Operational Regional Hurricane Modeling at NCEP: Plans and Advances

NATIONAL WEATHER SERVICE

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(with ongoing collaborations from AOML, DTC, NHC, GFDL, ESRL, FIU, OU, AER and others)

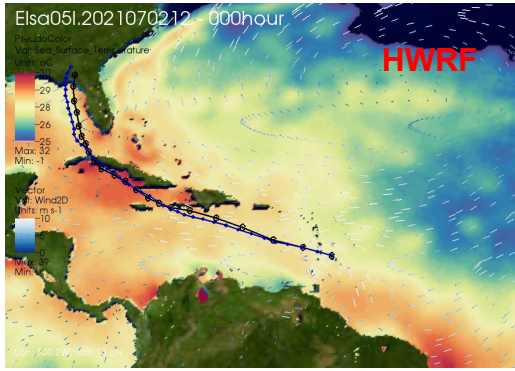
Outline

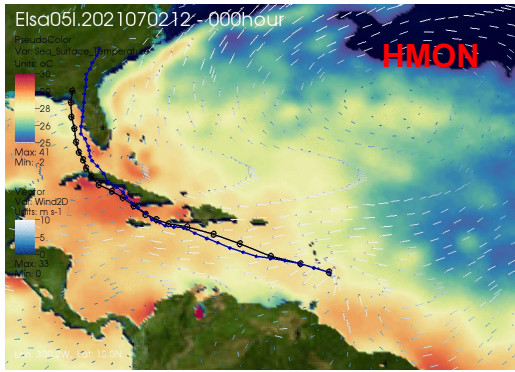
- **Operational hurricane forecast systems: HWRF/HMON**
  - GFSv16/RTOFS impact on HWRF/HMON
  - Track/Intensity forecast performance in 2021
  - HWRF/HMON porting on WCOSS2
- **Hurricane Analysis and Forecast System (HAFS) real time experiments for 2021 Hurricane Season**
  - Configurations
  - Track/Intensity forecast verification
- **HAFS Initial Operational Capability (IOC)**
  - Proposed configuration
  - Component development
  - TimeLine and future plan

Current Operational Tropical Cyclone Prediction Models at NCEP

	HWRF	HMON
Dynamic core	Non-hydrostatic, NMM-E	Non-hydrostatic, NMM-B
Nesting	13.5/4.5/1.5 km; 77°/18°/6°; 75 vertical levels; Full two-way moving	18/6/2 km; 75°/12°/8°; 71 vertical levels; Full two-way moving
DA and Initialization	Vortex initialization, Self-cycled hybrid EnKF-GSI with inner-core DA (TDR)	Modified vortex initialization, no DA
Physics	Updated surface (GFDL), GFS-EDMF PBL, Updated Scale-aware SAS, NOAH LSM, Modified RRTM, F-A MP	Surface (GFDL), GFS-EDMF PBL, Scale-aware SAS, NOAH LSM, RRTM, F-A MP
Coupling	MPIPOM, RTOFS, WaveWatch-III	HYCOM, RTOFS, No waves
Post-processing	NHC interpolation method, Updated GFDL tracker	NHC interpolation method, GFDL tracker
Operational forecasts	All global basins (NHC/JTWC), max. 7 TCs on-demand	NHC basins, max. 5 TCs, on-demand
Computation Resources	91 nodes in 98 mins	43 nodes in 100 mins

Hurricane Elsa, 05L, 2021





Note: Items in Green are similar/same; Items in Red are different

GFS v16 Downstream Impacts on Hurricane Forecast Models

Impact on HWRF

	Track Forecast	Intensity Forecast	P-W relationship	RI POD/FAR
NATL	Positive at all lead times (~5%)	Positive at most of the lead times, except for marginally negative at day 1 and 5.	Improved	Improved POD/FAR
EPAC	Significantly positive at all lead times, >20% at day 4-5	Neutral overall. Negative between hrs 30-60 but positive for longer lead times at Days 3-5.	Neutral	Degraded POD/FAR

Impact on HMON

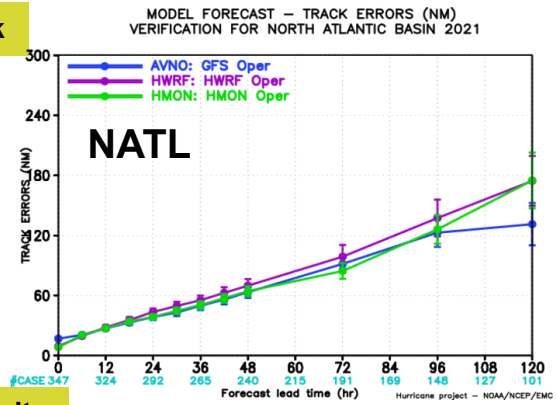
	Track Forecast	Intensity Forecast	P-W relationship	RI POD/FAR
NATL	Negative at all lead times after day-1 (<~5%)	Positive at all lead times, ~10% between day 2-4	Improved	Degraded POD Neutral FAR
EPAC	Significantly positive after day 1, >10% at day 4-5	Neutral before day 3, Significantly positive at day 4 and 5 (>20%)	Improved	Improved POD/FAR

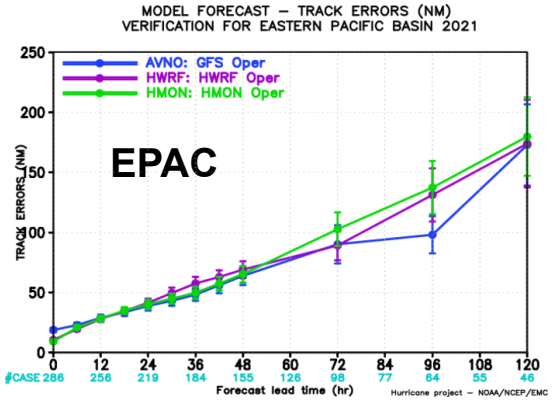
Note: Retrospective testing based on 2018-2020 storms

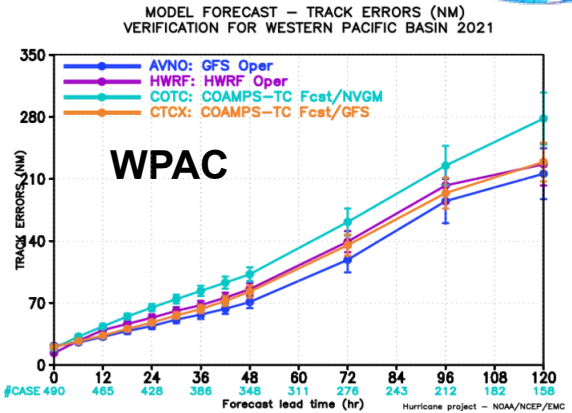
Operational HWRF/HMON/GFS

Track and Intensity Errors for 2021

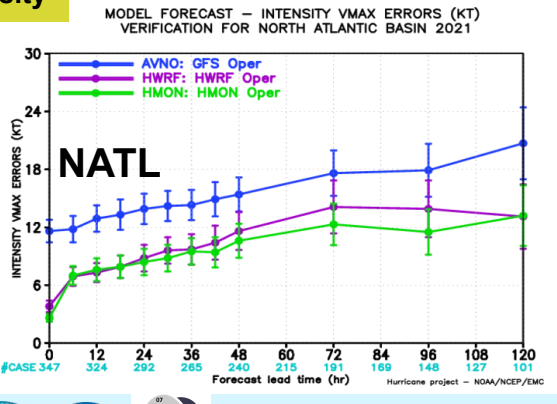
Track

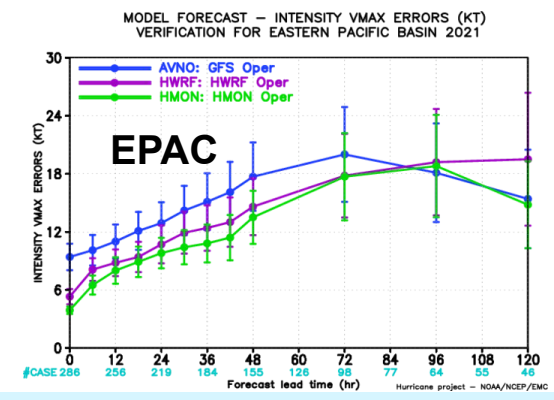


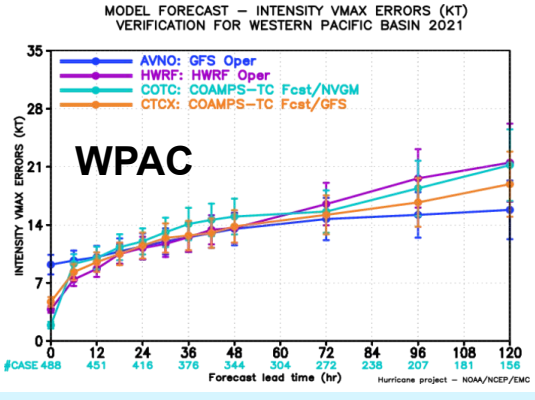




Intensity







Operational GFS, HWRF and HMON: 2021 Season Summary

- **NATL Basin:**
  - Operational HMON has the best intensity skill with HWRF matching skill for the first two days and then again on Day 5. Average max errors are ~ 12 kts at Day 5.
  - Operational HMON has the best track skill for Days 1-4 while GFS had the lowest track errors for Day 5.

- **EPAC Basin:**
  - Both HWRF and HMON had good intensity skill for days 1-4 and GFS and HMON for Day 5. Overall, intensity errors are higher than for NATL basin.
  - All operational models have similar track errors with GFS having the best skill for Days 4 and 5.

- **WPAC Basin:**
  - Operational GFS has the best track skill at all lead times.
  - Operational HWRF had the lowest intensity errors for the first 2 days with GFS doing well for the longer lead times.

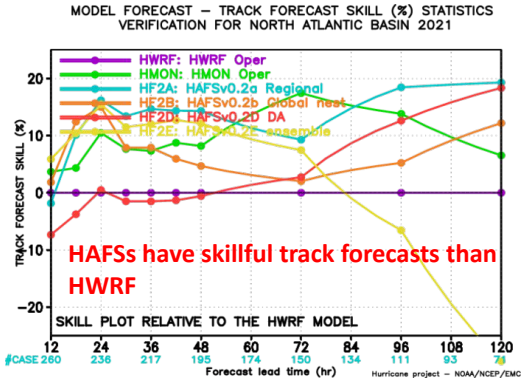
Transition to HAFS

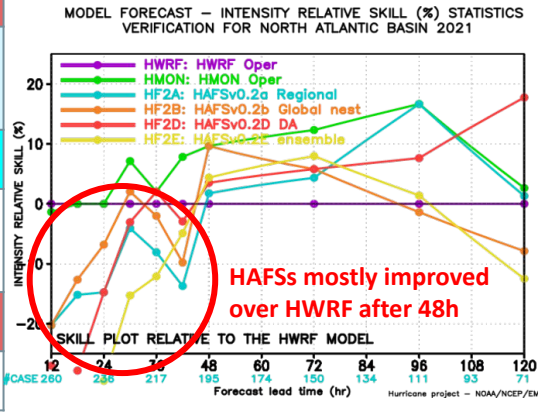
Hurricane Analysis and Forecast System (HAFS): A collaborative Project in the UFS Framework

- Develop UFS based cloud-allowing HAFS to replace current NOAA's operational hurricane forecast systems, HWRF and HMON
- HAFS Initial Operational Capability (IOC) is proposed for **implementation in FY23**
- All decisions on HAFS IOC based on EMC and NHC science evaluations
- Maintain current CONOPS:
  - max 5 storms in NHC AOR for HMON
  - max 7 storms for HWRF in all global basins (NHC, CPHC and JTWC) i.e. total max 12 storms
  - Requires two configurations for HAFS IOC

Real Time Demo of HAFS Configurations*

	HAFS-A	HAFS-B	HAFS-D	HAFS-E
Resolution/ Model top	~3km (ESG), L91/10hPa	~13-3km global-nest, L75/2hPa	~3km (ESG)/L91, 10hPa	~6km, L64, 10hPa
Domain	~94°×65°, 3121×2161	Global ATM:(C768), Nest ATM:~79°×43° OCN: ~330°×89°	~94°×65°, 3121×2161	~86°×58°, 1441×1081
IC/BC	GFSv16/3hrly	GFSv16/3hrly	GFSv16/3hrly	GEFS/6hrly
Coupling Ocean IC	CMEPS-HYCOM RTOFSv2	CMEPS-HYCOM RTOFSv2	CMEPS-HYCOM RTOFSv2	No ocean model NSST
Data Assimilation	No	No	Yes (addl:TDR, METAR, meso GOES-R AMVs)	No
Radiation	RRTMG (30min)	RRTMG(30min)	RRTMG(30min)	RRTMG(60min)
PBL/Surf GWD	M-TKE-EDMF/M-GFS orographic GWD	M-TKE-EDMF/M-GFS saGWD	M-TKE-EDMF/M-GFS orographic GWD	M-TKE-EDMF/M-GFS orographic GWD
CP/MP	saSAS/GFDL	saSAS/GFDL	saSAS/GFDL	saSAS/GFDL
LSM	NOAH	NOAH	NOAH	NOAH

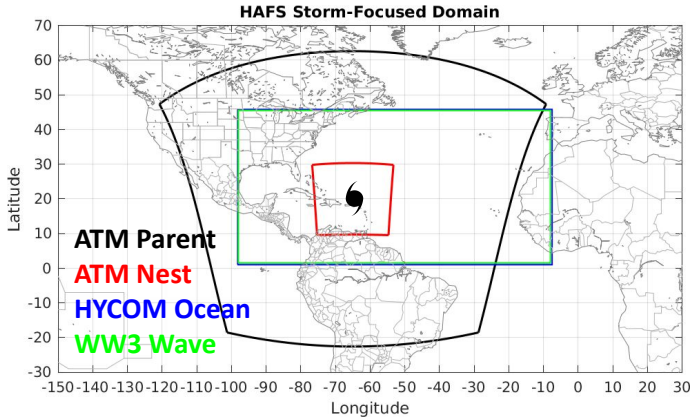




None of the HAFS configurations tested thus far contained moving nest capability.

HAFS IOC Primary Configuration -- Storm-centric with one moving nest

	Domain	Resolution	DA/VI	Ocean/Wave Coupling	Physics*	Computer resource
HAFS v1.0	Storm-centric with one moving nest, parent: ~86x86 degree, nest: ~19x19 degree	Regional (regular Gnomonic or ESG), ~6/2 km, ~L81, ~2 hPa model top	Storm inner-core DA, cycling for NATL/EPAC TCs, VI	Two-way HYCOM, one-way WW3 coupling for NHC AOR	HAFSv0.3A/GFS like CCPP physics suite	~6,000 cores per storm x 12 storms = ~72,000 cores



The primary configuration will replace current operational HWRF, providing TC forecast guidance in all global oceanic basins, **7 storms maximum.**

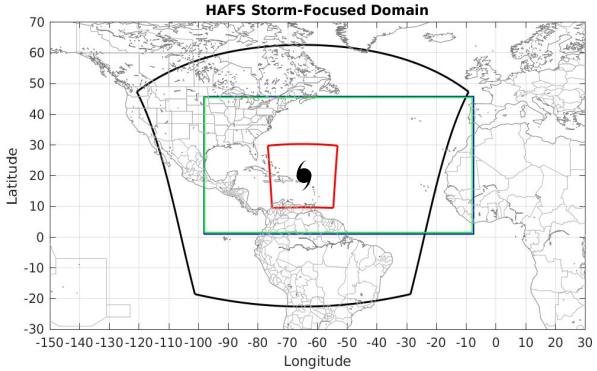
***A secondary configuration** will be derived using alternate physics to replace current operational HMON, providing TC forecast guidance in the NHC basins, **5 storms maximum.**

*Subject to change based on T&E and available computer resource
Expecting allocation of ~3.5x than currently used for hurricane models on WCOSS2

The HAFSv0.3A Baseline Configuration

(Based on the 2021 HAFS.v0.2A experiments)

- Use the feature/hafsv0.3_baseline
- 6-km for parent and 2km for moving nest, in regular gnomonic grids, L81 (2 hPa top) vertical levels
- Turn on topography smoothing for model stability
- dt_atmos=90s; parent: k_split=2, n_split=5, nest: k_split=5, n_split=9 for 2-km nest,
- updated saSAS convection; Noah MP; uGWPv1



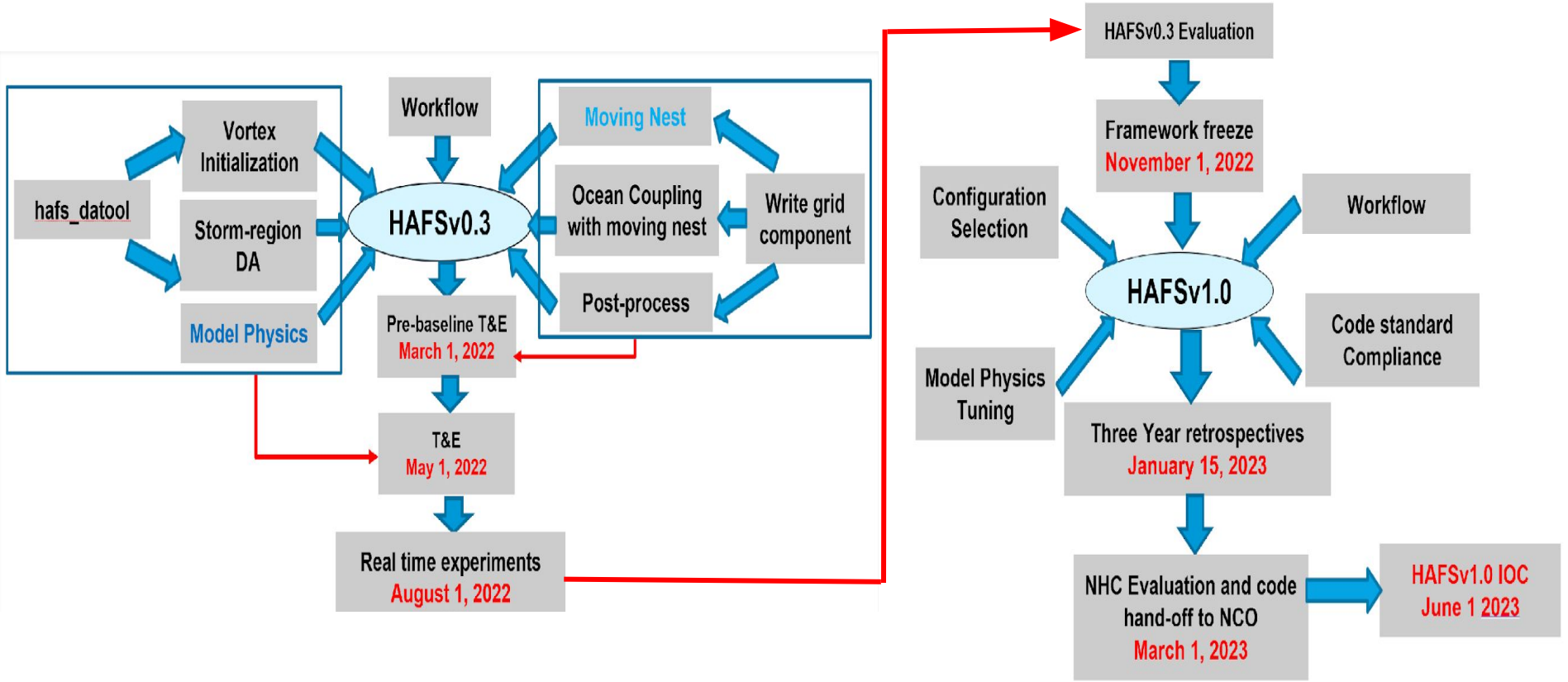
ATM Parent

ATM Nest

HYCOM Ocean

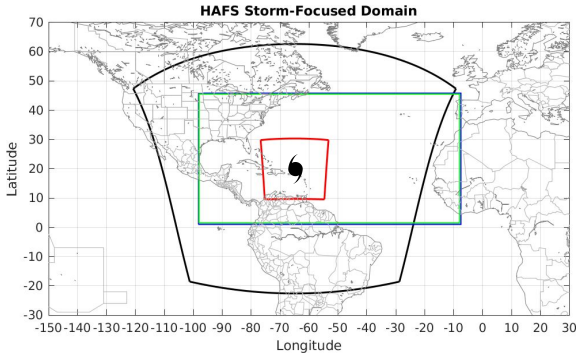
Wave Domain

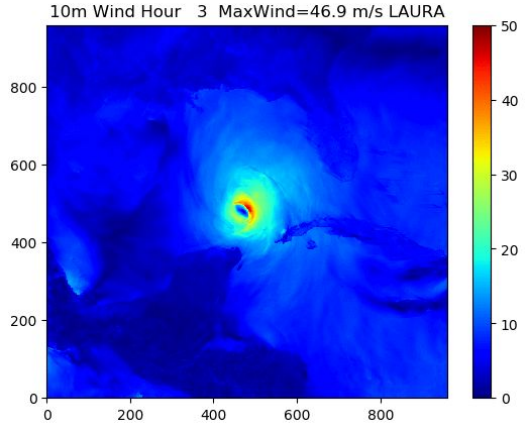
Critical Components of HAFS Development, T&E, and Timelines for Implementation



Summary and Future Plans

- FY22 Hurricane season – Operational HWRF & HMON have been ported to WCOSS2
- Hurricane Analysis and Forecast System (HAFS) real time HFIP experiments for the 2022 Hurricane Season (08/01 -- 11/01)
- FY23 – targeted for HAFS IOC





Thank You!

FY2021 HWRF/HMON Configurations for Different TC Basins

Model	Basin	Ocean Coupling	Wave Coupling	Data Assimilation	Ensemble DA	Vertical	Top
HWRF	NATL	POM RTOFS	WW3 1-way	Always	TDR/priority storm	75 level	10 mb
HWRF	EPAC	POM RTOFS	WW3 1-way	Always	TDR/priority storm	75 level	10 mb
HWRF	CPAC	POM RTOFS	WW3 1-way	None	None	75 level	10 mb
HWRF	WPAC	HYCOM RTOFS	None	None	None	75 level	10 mb
HWRF	NIO	HYCOM RTOFS	None	None	None	75 level	10 mb
HWRF	SH	HYCOM RTOFS	None	None	None	75 level	10 mb
HMON	NATL/EPAC/ CPAC	HYCOM RTOFS	None	None	None	71 level	50 mb

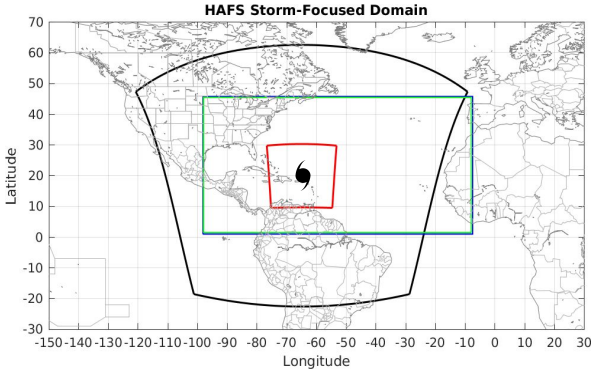
- EnKF self-cycled DA system for one TDR or priority storm
- 75 vertical levels with 10-hPa top for all global TC basins
- Ocean coupling for all global TC basins (POM for NHC basins, HYCOM for JTWC basins)
- POM RTOFS initialization for NATL/EPAC/CPAC basin
- One-way coupling to wave model for NATL, EPAC, and CPAC
- Sea surface wave IC/BC come from global wave model

The HAFSv0.3A Baseline Configuration

(Based on the 2021 HAFS.v0.2A experiments)

- The FV3ATM component
  - Use the feature/hafsv0.3_baseline branch with its subcomponents synced with their latest authoritative branches (as of 05/01/2021)
  - 6-km for parent and 2km for moving nest, in regular gnomonic grids with the L81 (2 hPa top) vertical levels
  - Turn on topography smoothing for model stability when moving nest interacting with steep topography, full_zs_filter = .T., n_del2_weak = 15 (24), max_slope = 0.25 (0.12/0.3/0.4)
  - GFSv16 netcdf files for IC; 3-hrly GFSv16 grib2 files for LBC
  - dt_atmos=90s; parent: k_split=2, n_split=5, nest: k_split=5, n_split=9 for 2-km nest, radiation time step: 1800s; LBC blending (nrows_blend=10)
  - Use the HAFS_V0_gfdlmp_nonsst physics suite
    - GFDL microphysic; RRTMG radiation; updated saSAS convection; MP-LSM; GFS surface layer with HWRF exchange coefficients; GFS EDMF PBL with HWRF modification; uGWPv1; Turning off the NSST component

ATM Parent ; ATM Nest,HYCOM Ocean Wave



- The HYCOM component
  - CMEPS based ocean coupling with the bilinear regridding method
  - 1/12-degree NATL domain (1-45.78N, 261.8-352.5E) with L41
  - Ocean IC from RTOFSv2 and persistent oceanic LBC
  - Atmospheric forcing from GFSv16 grib2 files for non-overlap area